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Ecology - Marine, rocky intertidal

The Biology of a High Isolated Tide Pool

Major Problem Report

ZOOLOGY 212

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Statement of Problem

During an early exploration of the Mussel Point area an interesting tide pool was discovered in a crevice in the rocks. The tide pool was very high, and was at first assumed to be stagnant. However, an examination of the animal life found in the pool soon proved that it was far from being stale, salty water, and was in fact a small scale cross section of every zone found in the rocky intertidal area. It was decided to make a study of the ecology of this pool in an attempt to see how the various animals lived and behaved. For the results of such a study to be of any real value, it was early realized that the pool should be kept in its normal condition. Therefore, a rule was made that no animals would be taken from the pool, none would be added to it, and the animals would be disturbed as little as possible.

Materials and Methods

The tide pool studied in this project was really a small pothole in the rocks. It is situated 75 feet due north of the triangulation point bench mark of the U. S. Coast and Geodetic Survey on Mussel Point, Hopkins Marine Station, Pacific Grove, California. The face of rock in which the tide pool is located faces east. The surface of the pool is 5 feet 3½ inches above mean sea level, or 8 feet 3½ inches above the 0 level of the tide tables.

The pool is in such a peculiar position, and of such a shape, that it envoked interest as to how it was formed there in the rock. From the shape of the bottom, it must have been formed by a boulder

which was continually agitated by the heavy surf.

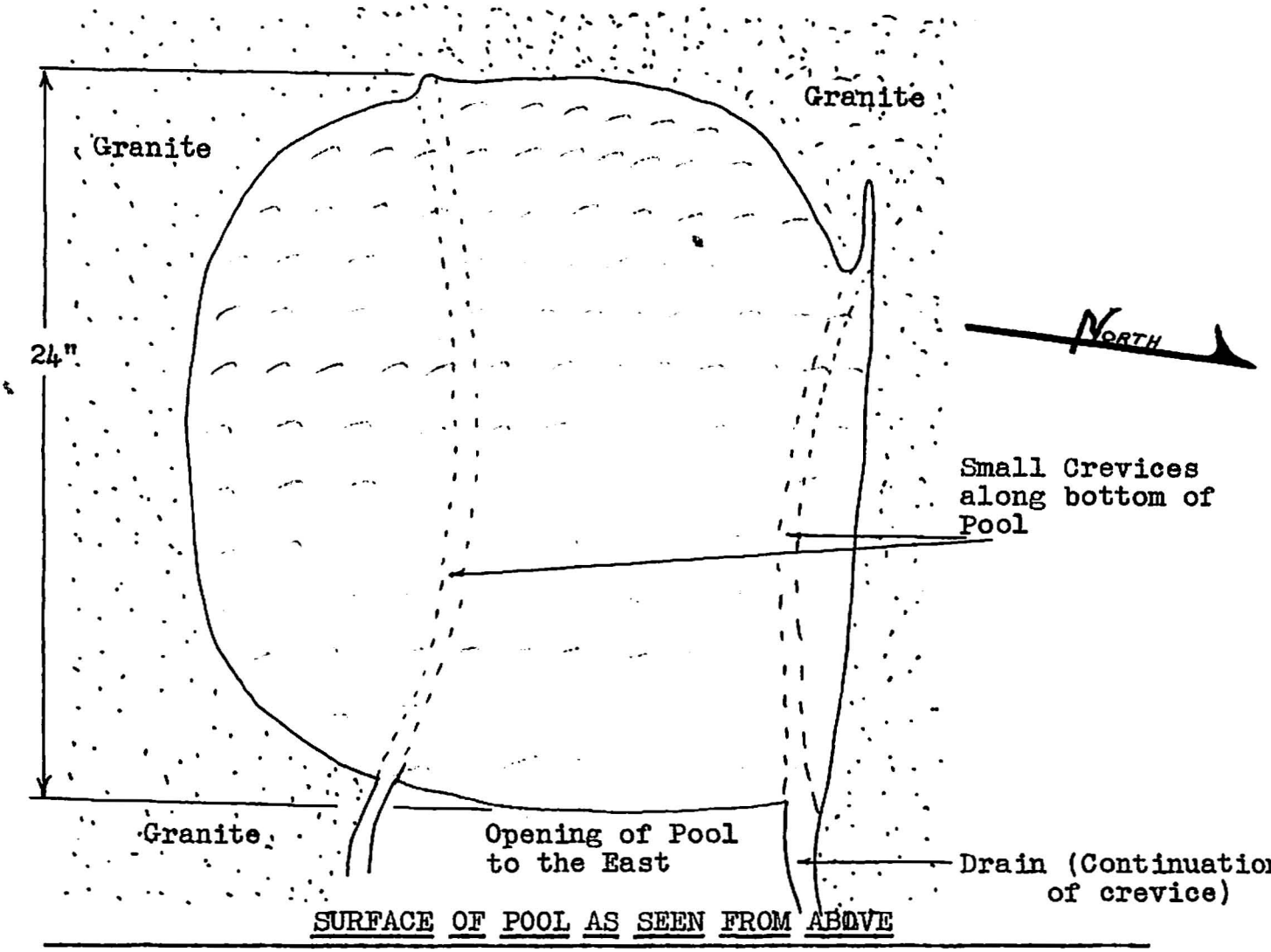
Plate I shows a surface view and cross-section of the pool. As can be seen, the tide pool is very small, being only 2 feet long, 1½ feet wide, and 1 foot deep; and contains about 8-10 gallons of water. The shape of the pool is quite regular, being in the form of a slightly flattened hemisphere. Were it not for two slight crevices running the length of the pool, it would be perfectly regular.

From the edge of the pool the rock rises vertically for eight feet on three sides, north, west and south. The only access to the pot hole is from the east, where it is barely possible to get one's shoulders in over the pool.

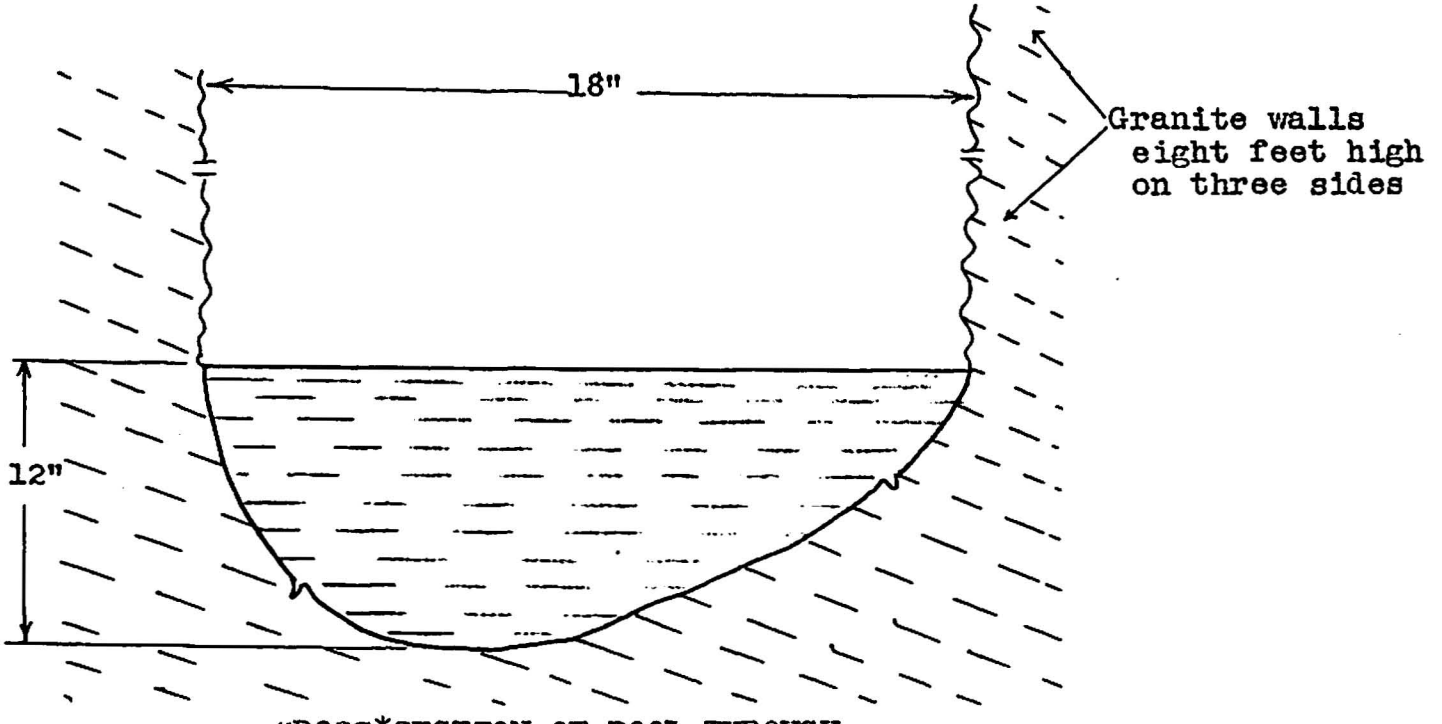
A large granite boulder 8 feet in diameter lies immediately seaward from the entrance, and the water which enters the pot hole must pass over the top of this boulder and fall about 3 feet down into the pool.

It is only at the highest tides of the day that any water enters, and during a heavy swell at high tide the force with which the sea breaks over the large boulder and flushes out the pool makes one wonder how any of the organisms in the pool can remain there and not be washed out. The level of the sea never gets up to where water flows into the pool gradually. Only high waves, funneled in by the many reefs further out, have sufficient force to break up over the rock and in to the pool. However, this area on Mussel Point resembles the open coast in the severity of the surf, and each day at the highest tides, hundreds of gallons

PLATE NO. 1



SURFACE OF POOL AS SEEN FROM ABOVE



CROSS*SECTION OF POOL THROUGH
THE CENTER

of cold, well aerated sea water flushes the pool out with nearly every incoming wave.

The excess water that is dumped into the pot hole gradually seeps out through two little channels on each edge of the pool. A few minutes after the pool has received an influx of water, it has drained back down to its normal level of one foot deep at the center.

In view of the above it is safe to assume that the salinity of the pool is the same as that of the ocean. This is supported by the fact that the pool is in shade most of the time. Only about four inches of the pool on the north side is ever in direct sunlight during July, and then only from 11:30 until 12:30 each day.

The temperature of the pool is also quite constant. Table I shows that the pool is usually about the same temperature as the sea, never varying more than 1.0 degree Centigrade from the sea temperature of the day.

The method of study followed in this project was merely one of observation. In very few cases were the animals disturbed at all, and then only as a last resort in order to find out what they were feeding on, or for identification of difficult species. In no case were any of the animals removed from the pool, nor were any added to it. Observations were made every day for the entire month of July, however, population records were kept only from July 9th to 30th. The pool was visited at all hours of the day, and also many observations were made at night in order to watch nocternal activity.

TABLE I

Temperature Readings

Date	Ocean Temp.* °C.	Pool Temp. °C.
July 10th	13.0	13.0
July 11th	13.0	13.5
July 13th	13.5	13.5
July 14th	13.0	13.0
July 16th	12.5	13.0
July 17th	13.0	13.0
July 19th	13.5	13.5
July 20th	14.0	14.5
July 21st	13.5	14.0
July 22nd	13.0	13.5
July 24th	13.5	13.5
July 26th	13.0	13.0
July 28th	13.5	14.0

*Ocean temperature taken on an exposed rock on Mussel Point.

Table II is a listing of all the species found in the tide pool, and a record of the numbers of individuals counted on various days of the month.

In order to keep the picture from becoming too confused, each group of animals will be treated separately, then an attempt will be made to discuss the relationships of the various species and individuals in the pool.

Observations and Discussion

In order to set limits to the area of observation, only the animals actually below the surface of the water, and those few touching the surface of the pool, were recorded in the population record kept from day to day. A few of the animals in the pool---such as Tegula, Thais and Acmaea limatula---were continually wandering into and out of the water. When not in the pool they would be above it on the rocks. Population counts were made only on those in the pool. The rocks above the pool contained many other animals which never ventured down into the water, and these animals will merely be mentioned here as being present. The most common of this group was Balanus glandula, and the rock above the pool was a solid mass of these barnacles. Next in order was Acmaea digitalis, Littorina planaxus, Acmaea scabra, Littorina scutulata, Gadinia sp., Mitella polymerus and Mytilus californianus. Corraline crust was found all over the rocks.

In addition to the animals listed in Table II, the pool was found to contain some sponges and tunicates. The most common sponge

TABLE II

Population Record

	9 July	11 July	12 July	13 July	17 July	18 July	19 July	20 July	21 July	22 July	23 July	24 July	25 July	26 July	27 July	28 July	29 July	30 July
Strongylocentrotus purpuratus	11	11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Leptasterias pusilla	7	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5
Leptasterias aequalis	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Tegula funebralis	24	20	35	25	25	20	20	20	24	28	25	30	20	10	15	15	14	18
Acmaea limatula	3	3	6	2	3	3	3	4	3	3	4	5	4	2	3	3	4	3
Acmaea mitra	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Acanthina spirata	2	1	2	2	2	1	3	2	2	2	1	1	3	2	2	2	1	3
Thais emarginata	2	2	2	1	1	1	1	2	2	3	4	5	4	3	4	2	2	3
Crepidula adunca	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mytilus californianus	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Tonicella lineata	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mopalia muscosa	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pachygrapsus crassipes	12	9	10	10	11	9	10	12	11	7	8	10	5	6	10	14	10	14
Petrolisthes cinctipes	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pagurus samuelis	35	30	25	20	25	20	22	23	24	20	22	34	25	15	20	28	25	24
Balanus glandula	Over 100 individuals on Tegula, Mytilus, & Crabs																	
Tetraclita s. rubescens	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Mitella polymerus	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Serpula vermicularis	10	10	10	10	10	10	10	11	11	11	11	11	11	11	11	11	11	11
Spirorbis spirillum	Average 10 per sq. inch all over bottom of pool																	
Terebella sp.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cirriformia sp.	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Sabella sp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Physcosoma agassizi	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

found was the red encrusting Plocamia karykina. This bright red sponge occupied an area of about one square foot on one side of the pool, and was found in smaller patches elsewhere. An unidentified yellow sponge belonging to the Order Dendroceratina was * found in a restricted area along the side of the small crevices in the bottom. This sponge is very soft and apparently has no spicules.

The only tunicate found in the pool was of the genus Eudistoma. The colonies were in small pedunculate groups, and the color was a very pale yellow. There were about five or six small groups ½ inch in diameter found along the south (and most shaded) side of the pool.

The main groups of animals will be taken up not in a phylogenetic order, but in the order in which their presence was first noted by the observer.

Echinoderms

On looking into the pool, the first thing the observer noted was four large purple sea urchins. After making a careful search of the crevices, seven more small Strongylocentrotus purpuratus were found. The small ones were all a very light green color, with whitish spines. Most of them were well hidden in crevices or wedged in between a mussel and the wall. Toward the end of the observation period, the largest individual of these smaller urchins began to get redish tips on its spines. This individual was about 1½ inches in total diameter, therefore it was quite obvious to the observer that in this tide pool at least the purple sea urchins were nearly full grown before they became purple.

* Possibly an extreme color variant of Xylophilaplacidus R. L. S.

During the first two days of observation one of the adult urchins was up near the surface of the pool, and in such a position that the incoming water at high tide would fall directly on it. The next day this urchin was missing from the pool. Either it was removed by some collector, or else it was washed out during the time of high tide. This left ten urchins in the pool, and all of these remained during the month they were studied.

The small sea urchins seemed to be much more active, as far as movements go, than the adults. The adults were relatively sessile, but each day the small ones were found to be in new locations. They rarely moved more than a few inches, however.

As will be seen on Plate I, there were two crevices which ran the full length of the pool. These were V-shaped and only about 1 inch deep and ½ inch across the top. The sea urchins were all lined up along these two crevices. The larger ones had a slight dish-shaped depression in which they remained. This relationship is illustrated by Figure 1.

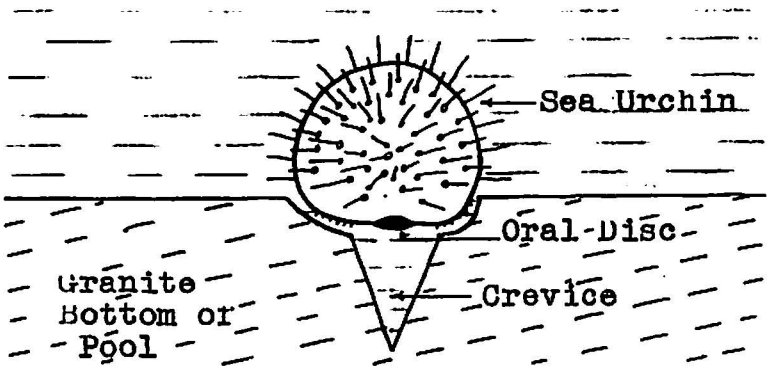


Figure 1

In the position shown in Figure 1 the sea urchin always had its oral surface in contact with a considerable amount or water. This may be of value in feeding, for small organisms could be removed from the water.

One day a littorine snail was accidentally knocked into the pool and landed on the spines of one large urchin. The spines in the vicinity of the snail immediately turned away and allowed the snail to sink down between several spines. Tube feet were attached to the littorine, and the snail was held close to the body of the urchin. It appeared that this was a defence measure, for in this way the foreigh body would be in a position where the pedicellariae could act. After a short time, the spines and tube feet, working together, started to roll the snail over and over, and gradually it was moved down towards the oral side of the sea urchin. When the snail reached a point near the side of the pool, its foot was extended to the wall, and it started to move away. However, before it got very far the tube feet attached to it pulled it back. Soon after this the urchin rolled back allowing the oral surface to be seen. The snail was worked down under the oral surface, then the sea urchin clamped down hiding the snail from view.

All of the above was very suggestive of a carnivorous habit on the part of S. purpuratus. In order to find out what happened to the snail, the observer waited ten minutes, then pried the sea urchin loose from the rocks. The snail was being held up against the jaws very firmly by the tube feet; the orifice of the snail's shell was outward from the jaws of the urchin. The sea urchin was

replaced in its original position, and the observer assumed that the matter was settled. However, in a minute or two it was noted that the sea urchin had left its position and was moving slowly across the pool. Back in the crevice the snail had been dropped. On examination, the snail exibited no evidence that the experience had harmed it in the least, and soon crawled away. Perhaps if the urchin had been left alone it would have eventually cut a hole thorugh the shell and eaten the snail. Several sea urchins were collected from other pools and placed in an aquarium in an attempt to duplicate the above, but without success.

One thing S. purpuratus was definitely seen to eat, however, was a piece of the sea weed Iridophycus flaccidum. A large piece of this alga was washed into the pool, and settled to the bottom near one of the large sea urchins. The urchin slowly moved over to the alga, attached tube feet to the pla nt, and worked it down under the oral surface. Later when examined, the alga had several holes in it below the jaws of the urchin. During an observation later in the day another sea urchin was feeding on the same alga.

As was said above, the large sea urchins are quite sessile, but once they leave their "home" position they don't return. Early in the study one left its depression in the rocks, and never returned to it.

The S. purpuratus presumably had no enemies in the pool, and were free to go where they pleased. Only one large Pachygrapsus equalled them in size, and the crab never seemed to bother them.

The only other Echinoderms in the pool were the small six-rayed stars Leptasterias pusilla and Leptasterias aequalis. These had to be examined very carefully in order to differentiate species. The small L. pusilla predominated with seven individuals present originally, and five later on. Only two L. aequalis were found, and they remained in the pool all the time. These latter two were quite large, and were always moving along up near the surface of the pool.

The food habits of L. pusilla were not observed, for most of the time these small sea stars were down in the crevices. However, the two large L. aequalis were continually supplying hermit crabs with empty small Tegula shells. At least once every few days one or the other of the two L. aequalis were seen humped up over a small Tegula. Were it not for the fact that these snails were continually crawling down off the rocks into the pool their numbers would soon have been exhausted.

The L. aequalis often were seen moving slowly over the smaller Mytilus in the pool, however, they were much too small to do the mussels any damage.

All of the sea stars in the pool definitely showed most of their activity at night.

Molluscs

The gastropods had the most numerous species represented in the pool of any group present. Tegula funebralis was the most common snail, and although the numbers varied from day to day there were usually about 20 in the pool. The great fluctuations shown

in Table I were due mainly to the fact that the snails were continually migrating in and out of the pool. They were very active at night gliding along scraping off encrusting algae with their radulae. There were many Balanus glandula on several Tegula shells, and on one Tegula which never seemed to leave the water, the one Crepidula adunca in the pool was located.

There were never very many Thais emarginata below the surface of the water. Many were found above the pool, and at night two or three could usually be found moving in and through the corraline Calliarthron on the edge of the water.

The few individuals of Acanthina spirata behaved very much like Thais. However, they remained in the crevices near the surface next to a group of mussels. None of the snails were ever seen on the Mytilus.

There were two species of limpets in the pool. Acmaea mitra was represented by two individuals located deep in the pool, and never once were these limpets observed to shift position. In contrast to A. mitra, the Acmaea limatula present were quite active moving into and out of the water. Most of the individuals were small, and were always found along the edge of the water, either above or slightly below the surface. They never went down deep into the pool. One small individual rode on the shell of a Tegula for several days.

Mytilus californianus was the only pelecypod definitely identified, however, on several occasions the incurrent and excurrent siphon of a probable rock-borer could be seen pushing up through

the debris in one of the crevices. In all there were 16 fairly large mussels below the water's surface. Most of them were encrusted with a red algae making them difficult to see. Balanus glandula was also present on many of the mussels. As far as could be determined, none of the animals in the pool caused Mytilus any harm. The mussels always had their valves gaping open with a current of water flowing through.

Their were three chitons in the pool, two large Mopalia muscosa and one small Tonicella lineata. Both of the Mopalia were over 2 inches long, and were capable of considerable movement. They would often remain quiet for several days, and then would start moving and keep going until they had circled the pool several times. Their path was usually around the pool at the water's edge. As they moved slowly along, the edge of one side of the girdle would be extending above the edge of the water. Their food seemed to be algae which grew only at the surface of the pool.

The little Tonicella lineata was barely half and inch long, and its movements were one of the most constant and stable things in the pool. One could almost calculate out which spot in the pool this chiton would be located at any specific time. The movement was extremely slow, but was very constant. If one would watch carefully for a few minutes, movement could be detected any hour of the day. The chiton always remained in the very bottom of the pool, and made a path in the form of a circle 8 inches in diameter. The pool bottom was always very clean with little detritus present, and this small chiton seldom deviated from its path.

Arthropods

The crabs and barnacles made up a considerable portion of the fauna of the pool in numbers of individuals if not in numbers of species.

The most conspicuous crab was Pachygrapsus crassipes, and one large individual was quite definitely the ruler and master of the tide pool. This crab was marked at the beginning of the study, and was never found to be far from the pool. The numbers of Pachygrapsus varied from day to day, but was relatively constant. Most of them were marked, and it was found that during a high tide some of the crabs were washed out. However, they were probably trapped down below the large boulder in front of the pot hole, for most of them would come wandering back into the pool after the tide had gone out.

The one large Pachygrapsus mentioned above allowed all the small crabs to wander as they pleased, but whenever a good sized one would try to get into the pool, he was driven out. Thus the population consisted of one large Pachygrapsus and usually 8 or 10 small ones. They would feed on any animal matter washed into the pool, and occasionally were able to pry a limpet off the rocks.

The smallest crabs spent most of their time below the surface of the water in crevices and among the corraline algae. However, the larger ones were most often observed up on the rocks bubbling away. At night they became quite sluggish and one could reach down and pick one up easily without his running away.

The two porcelain crabs -- Petrolisthes cinctipes -- were never seen out walking in the pool. They were very retiring, and often the most one could see of them would be a thin chelae, long red antennae, or an orange maxilliped sticking out of the crevice where they were continually hiding. Even the slightest agitation of the water would cause them to completely disappear. On one occasion the cheliped was seen to grab at a small hermit crab, but no other evidence of feeding or other activity was observed.

Pagurus samuelis was the only species of hermit crab in the pool. These were the most numerous actively motile individuals observed. Their numbers averaged about 25 per day, and varied from day to day. When a count was made immediately after high tide the numbers present were relatively low. It was found, by a system of markings, that these crabs were washed out during the influx of water at high tide, but they were trapped just outside the pool, and soon after high tide would wander back into the pool. Many individuals were lost, and never came back, but most of them did return. Other new one's entered the pool from time to time from sea ward, and this kept the numbers fairly constant.

The hermit crabs were active at all times and fed on anything the Pachygrapsus dropped.

Balanus glandula, next to Spirorbis, was the most numerous animal in the pool, but was even more numerous above the water surface. The remarkable thing about Balanus, considering it numerical importance in the pool, was that it was always found residing on some other animal, and never attached to the rock walls of the pool. The most obvious reason for Balanus not being on the bottom

and edge of the pool, was that the pool was encrusted with a very heavy layer of red algae. This algae would probably smother the small barnacles. The majority of individuals were present on Mytilus, but many Tegula carried colonies on their backs.

Tetraclita squamosa rubescens was represented by three fairly large individuals. These were located on the sides of the pool near the surface. Judging from the way these individuals were choked up with red algae, it is no wonder that the smaller Balanus can not live there. One large Tetraclita had an orifice barely 1 millimeter in diameter through which to extend it appendages. The encrusting algae was gradually suffocating it. Another individual was gradually being overgrown by the red sponge Plocamia.

Eight large Mitella polymerus were located in a colony in one of the crevices. They were up near the surface, and at normal pool level were barely under water. As common in other localities, these barnacles were situated near a group of Mytilus.

Annelids

There were five families of the Order Polychaeta represented in the tide pool. Spirorbis spirillum was very common, and about 10 small red patches signifying gills could be counted per square inch of pool bottom. These small serpulid worms were found to be very sensitive and would withdraw their tentacles quickly when the water was disturbed in any way.

Eleven large Serpula vermicularis were distributed around the pool. These polychaetes would withdraw their gills quickly if a crab moved suddenly over them, but they seemed quite insensitive

when a crab slowly brushed by the gills. It was supposed that the worms would withdraw their gill filaments when water was flushing into the pool, but observation proved that during influxes of water the gills were fully extended. It amazed the observer that the gills were not broken off by the force of the water.

The few individuals of Terebella and Cirriformia were found down deep in the crevices covered by little bits of shells and sand grains. Identification of these were very difficult. Their long hair-like tentacles were continually sweeping the bottom.

One lone individual Sabella was found in the pool. It was located near the surface, and its large brownish gills were nearly always extended. During influxes of water the membranous tube would bend about 90 degrees, but would soon assume its former shape, and all this time the worm would not withdraw its gills.

Fifteen sipunculid worms were observed, and after some difficulty were identified as Physcosoma agassizi. During quiet periods these worms would have their necks extended out, and would be sweeping the bottom. However, during water influxes the necks would be pulled back in. The small tentacles were never visible.

Conclusion

From the above it is obvious that in a tide pool of the sort studied, one has a sort of miniature cross-section of the intertidal. The factors influencing any populations in a given area--wave action, type of bottom, and exposure--were fairly uniform in the pool. The wave action, or the twice daily influxes of water, was always of about the same intensity as a result of the position of the pool. The bottom was mainly solid rock, but in the crevices enough sand was found to support a few sand-loving species. The bottom remained constant. For the animals in the pool, exposure was no problem, for they were always covered. Excess water dumped into the pool at high tide would quickly run off leaving the pool at a definite height. The pot hole was located in a granite face, and was in deep shade most of the time. This, again, was dondusive to a constant and stable environment in the pool.

The tide pool was not, however, a complete unit in itself. For most of the animals present, food came in only with the great gushes of water which poured over the rocks at high tide. Thus, it was found, many animals were able to live side by side, ignoring one another so to speak, and waiting for high water to bring in food and clean fresh water. Of all the animals present, only the crabs and the star fish were active carnivores feeding on other members of the community.

The food for most of the species represented was algae which lined the pool, and from all appearances was replenished as fast as it was eaten.

The pool was probably supporting about the maximum number of individuals possible, for it was noted that the numbers of animals remained fairly constant in the pool. It was true in the case of the motile animals, that whenever one individual left the water, by one of several means, there seemed always to be another standing by to take his place.

The pot hole proved to be a sort of asylum for the majority of animals present. The large migratory predators of the normal intertidal area were kept out, and thus a considerable amount of protedtion was achieved.

Assuming that there were individuals of both sexes present in most species, the chances of fertilized eggs being produced and washed out to sea was considerably greater than they would have been in the open ocean.

Taken as a whole, the tide pool studied was a fairly uniform environment, and was thus able to support a great variety of species and individuals.

Summary

A small isolated tide pool was studied quite intensively over a period on one month. A census of all animals present was taken, and a population record kept daily for the month. Fluctuations in the numbers of individuals were noted, and reasons for these fluctuations sought.

The behavior and feeding habits of the various animals were noted, and an attempt was made to relate the animals to their environment.